Robotics Overview

Austin Eliazar

Ron Parr

CPS 270

What is "Robotics"?

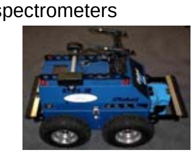
- Mechanical man ideas go back at least to the Greeks
- Term comes from Czech playwright Karel Capek (or perhaps from his brother Josef) ~1917-1921
  - "robota" (obligatory work)
  - "robotnik" (serf)
- "Robotics" first used by Asimov in 1950
- Agents with physical embodiment
  - Sensors
  - Effectors
- Human-shaped robots = humanoids

Common Robot Applications

- Industry and agriculture
  - Building cars
  - Harvesting crops
- Mapping and Exploration
  - Mines
  - Mars
  - Military Intelligence
- Transportation
  - Delivery of mail/equipment
  - Military applications
- Medical devices
- Household aids
  - Lawn mowers
  - Vacuum cleaners
- Entertainment
- Human augmentation

What is a Robot?

- Robots actively interact with the real world
- Sensors
  - Observations of the environment are crucial
  - Internal sensors : Odometers, pressure, inertial
  - Range finders : Sonar, radar, laser, infrared, GPS
  - Descriptive sensors : cameras, spectrometers
- Effectors
  - Locomotion
    - Wheels, legs, snake-like joints
    - Establish the robot as *mobile*
  - Manipulation
    - Arms, hands, tools
    - Most commonly used in factory automation



Perception

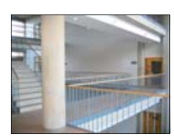
- Sensors are noisy
- Perception is often a probabilisitc inference problem
  - Want P(S|O) (state given observations)
  - Model P(O|S) (sensor model)
- Use Bayes rule

$$P(S \mid O) = \frac{P(O \mid S)P(S)}{P(O)}$$

NASA's K9 Mars rover

Localization

- Determining the robot's current state in the world
  - Location
  - Position
  - Orientation



- Assumes a model of the world
  - Problems arise from noisy sensors
  - Even with perfect sensors, ambiguities arise
  - Addressed in greater detail next lecture…

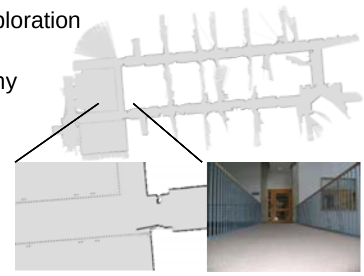
Mapping

- Creating a model of the world
  - Entire environment (D-Wing, surface of Mars)
  - Specific object (rock, building)
- Sensors are not omniscient
  - Only see small portions at a time
  - Collect a subset of possible information
  - Noisy sensors
- Readings must be combined
  - Different views : registration
  - Different instruments : sensor fusion

D-Wing of LSRC (2nd Floor)

SLAM

- Simultaneous Localization And Mapping
  - Search and Rescue
  - Planetary Exploration
  - Demining
  - True autonomy
- Uncertainty
  - Sensors
  - Motion
  - History



Robot Effector Complexity

- Degree of Freedom (DOF)
  - Independent direction of movement
  - Rigid body in space = 6DOF (X, Y, Z, yaw, roll, pitch)
- Dynamic state
  - Velocity : DOF x2 for derivatives
  - Acceleration : DOF x3 for second derivatives
- Effective DOF can be > true DOF
  - e.g. car (2 actual, 3 effective)
  - effective > true = nonholonomic

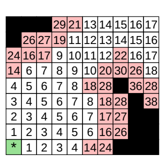
Stanford University's "Stanley"

Motion Planning

- Planning is typically done in configuration space
- Configuration space includes
  - Physical position
  - Orientation
  - Joint Angles
- Path planning problem: Find path between two points in configuration space

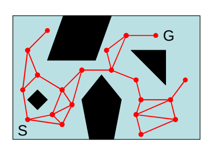
Approaches to Planning

- Cell decomposition (discretization)
  - Break continuous space into discrete cells
  - Plan using search or MDP (covered later) techniques
  - Allows variable cost/risk
- Discretization issues
  - Doesn't scale well
  - Only an approximation



Approaches to Planning

- Skeletonization
  - Define a graph of connected points in free space
  - Planning = search on the graph
- Problem: Constructing the graph
- Probabilistic Road Map (PRM)
  - Randomly spray points
  - Discard illegal ones
  - Connect nearby ones
  - Plan on resulting graph
  - Incomplete in general
  - Succeeds WHP under some assumptions



Executing Plans

- Skeletonization assumes deterministic movement – may require replanning
- MDP techniques (discussed in detail later) devise a universal plan for all (discrete) states
- Control theory can be used for continuous problems to keep the robot on track

Reactive Control

- Some say that roboticists over-formalize
- Reactive control advocates hard coding simple, reactive mechanisms
- Works very well for some problems
- Does it scale?

Conclusions

- Robotics is a huge field – as large as AI itself
- Fertile ground for many AI techniques
  - Machine Learning
  - Probabilistic inference
  - Vision
  - Natural language comprehension
  - MDPs and POMDPs
  - Particle Filters
  - Information Theory
- Involves many issues not directly addressed by typical AI approaches
  - Sensing issues
  - Effecting issues
  - Real-time decisions
  - Unknown environments